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MBA PROFESSIONAL REPORT

Cost Analysis and Effectiveness of Using the Indoor Simulated Marksmanship Trainer (ISMT) for United States Marine Corps (USMC) Marksmanship Training

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June 2011

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LIST OF ACRONYMS AND ABBREVIATIONS

ACRM	Advanced Combat Rifle Marksmanship
ASVAB	Armed Services Vocational Aptitude Battery
BCRM	Basic Combat Rifle Marksmanship
DoD	Department of Defense
FATS	Fire Arms Training Systems, Incorporated
FRM	Fundamental Rifle Marksmanship
GSA	United States General Services Administration
HCI	Human and Computer Interaction
HMD	Head-Mounted Display
ICRM	Intermediate Combat Rifle Marksmanship
ISMT	Indoor Simulated Marksmanship Trainer
ITS	Individual Training Standards
KD	Known Distance
LF	Live Fire
LFT	Live-Fire Training
MBA	Master of Business Administration
MMTSS	Mobile Military Training Simulation System
MOS	Military Occupational Specialty
MOVES	Modeling, Virtual Environments and Simulation
NCO	Non-Commissioned Officer
NPV	Net Present Value
NPS	Naval Postgraduate School
O&S	Operations and Support
PM	Program Manager
PMI	Primary Marksmanship Instructor
PMTRASYS	Program Manager for Training Systems
R&D	Research and Development
ROI	Return on Investment
SOP	Standard Operating Procedure

SRS	Service Rifle Simulator
VE	Virtual Environment
VR	Virtual Reality
VRT	Virtual Reality Training

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I. INTRODUCTION

A. PURPOSE OF THE STUDY

There may be benefits of using virtual simulation to train Marines in Basic Rifle Marksmanship. For more than a decade, the Department of Defense (DoD) has recognized and researched the potential use of virtual technology training environments. The intent of this research is to present and analyze data pertaining to the cost, benefits and effectiveness of those methods in Marine Corps marksmanship training.

The research conducted by the DoD has largely focused on the use of specially-developed and relatively high-fidelity PC-based virtual simulators. The approach has included field assessments of virtual training technologies with Marines in realistic training settings and more scientifically rigorous experimentation in a laboratory setting. Some of the research in this field has demonstrated that virtual simulation can adequately support a variety of Marine activities, and is effective for training both individual and collective Marine skills (Yates, 2004).

During the past few years, there have been changes in both the training needs of the DoD and the menu of training solutions available. These changes present both new challenges and new opportunities. The DoD has recognized a need to train Marines to be adaptable, capable of responding to rapidly changing situations, and to be proficient in high-intensity combat operations. The training objectives are especially important, given changes in doctrine describing how Marines expect to fight in the future, as well as the lessons learned in current operations in Iraq and Afghanistan. Within this new context, it is proposed that virtual simulation be used not only to train for relatively straight-forward combat operations, but also to train for the decision making needed by Marines in the current operating environment.

This change in training requirements has implications for simulation requirements. At the same time, advances in computer technology and processing power have made it possible to generate the graphics and calculate weapons and environmental

effects with moderate costs at just 1% of the cost of the graphics generators of a decade ago. However, the cost of the interface devices (head-mounted or projection displays, position trackers, and instrumented mock weapons) have declined only slightly during the same period, making them a much larger contributor to the cost of simulators than the computer itself.

B. MARINE CORPS MARKSMAN

The United States Marine recruits are a major foundation upon which our nation heavily relies for revitalization of our fighting force. A primary objective of the Marine Corps is to conduct warfare from the land, sea, and air to any region in the world. The land-based component of the Marines needs to include technical leaders as well as capable marksmen.

Figure 1 is an example of the M16A2 service rifle. The M16A2 rifle is the primary weapon used by a Marine to wage war against enemies of the United States. Therefore, Marines must be highly proficient with the M16A2. Marine recruits begin their instruction with this weapon at a Marine Corps rifle training range.

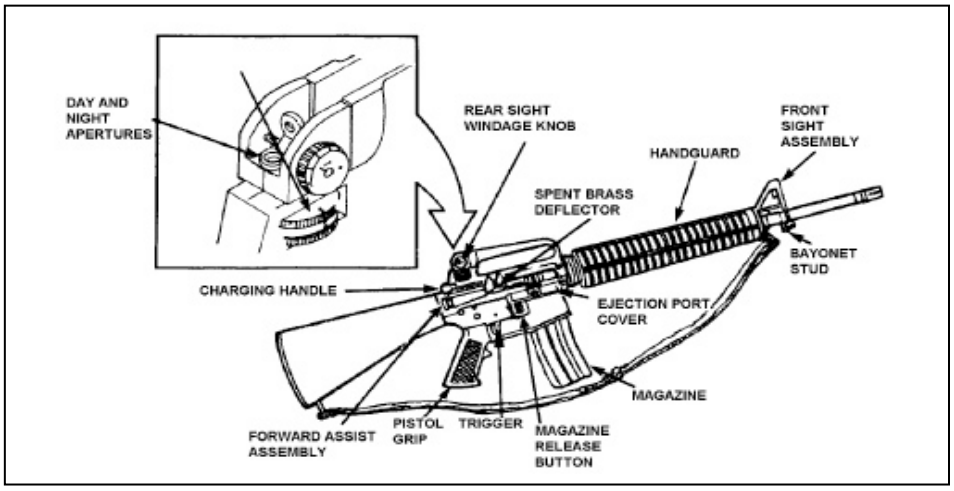

Figure 1. M16A2 Service Rifle

Marines are required to learn the fundamentals of marksmanship through five incremental phases of training (listed in Appendices A and B). After learning the

fundamentals of marksmanship, Marines then learn about combat shooting skills. As each of the elements of training is mastered, Marines move from one training objective to the next until they have mastered all of the building blocks of their training continuum. Each table of training requires a minimum amount of ammunition and targets. All of these materials are expensive for the Marine Corps and add up to millions of dollars. This training is essential in order to obtain dominance over the enemy. The Marine Corps must continue to train Marines in marksmanship for future engagements. However, the Corps must also find ways to make this expense more manageable.

Years ago, the needs of the Marine Corps were different from those of today. Marines of the past trained primarily in outdoor environments. Today, they are more capable technologically. Marines understand computers much better than they did ten years ago. While the concept of aircraft or vehicle simulators is not new, the capabilities and features of many of today's systems are cutting edge. With technology, the military's virtual world is almost limitless. Current virtual training capabilities can allow commanders to plan encounters on the ground, provide realistic training opportunities at every level, and capitalize on the skills of this new breed of Marines. The impact of the emerging virtual reality training on the Marines may have the potential to change future training.

C. THE PROMISE OF VIRTUAL REALITY

The realism of virtual training has improved over the years. Virtual training allows Marines to familiarize themselves with weapon systems that they will most likely encounter while deployed. Combining virtual with live training creates huge possibilities for commanders. Entire units have rehearsed training before going out on a range. A Marine can run through an entire live-fire range in a virtual environment before ever going to the range. If a Marine wanted to set up the same small-arms firing range in one location and do the same procedure at a second location, it would take about three weeks

to set up one week's worth of training. The firing range can be completely simulated so nothing is sacrificed out of the platoon or company in order to have a complete training environment.

Live training generally has a higher cost than training with virtual systems. With virtual systems, the ability to control costs could be a benefit for training. Entire platoons can be trained in real-world virtual firing ranges all day long for much less money than it takes to deploy a group to a live-fire range. By no means does this replace going to the field and training, but it does enhance training by making sure Marines are better prepared when they get there, thus making training more efficient. Trainers have discovered that virtual environments can familiarize Marines with some of the most complex weapon systems in the military. Military officials and video game studios have partnered to create realistic, immersive virtual scenarios that help Marines acclimate to various combat environments and situations ("The Virtual Battles," 2010).

D. THE INDOOR SIMULATED MARKSMANSHIP TRAINING SYSTEM (ISMT)

The ISMT is a completely self-contained high technology rifle range. It can support training and marksmanship on demand in any environment (Appendix C). The system is designed to support a multitude of lethal and non-lethal weapons-based scenarios to give users a robust array of simulated training. Specific to this MBA project, increased use of the ISMT may be able to provide the Marine Corps recruits the basic rifle training required for qualification at a fraction of the cost.

Meggitt Training Systems (MTS)—based in Suwanee, Georgia—produces "digital technology and laser-emitting weapons to provide realistic weapons training" to military personnel in the United States and abroad (Appendix F). MTS simulators use an integration of video and digitized imagery with laser emitting firearms that feel and look just like the actual weapons our forces use (Appendices D and E). These systems have the ability to reload and recoil after each shot. The technology uses film that reproduces the backdrop of simulation. Although participants are actually conducting their fire

exercise inside a darkened studio, projected images of various scenarios—that is, known distance (KD) ranges—can create a sense of a particular environment. Such VRT systems allow initial entry Marines to simulate basic rifle training in a highly realistic KD range scenario (Meggitt Training Systems, n.d.). Interactive simulation of live-fire training has been in the minds of military planners since the explosion of computer technology in the early 1980s. There has long been the understanding that training on live-fire (LF) ranges was costly and could be streamlined and still provide the same, if not better, quality of Marine training with less expense. Using the ISMT system could save the USMC on ammunitions costs, weapons wear, and manpower.

Using the MTS training environment also allows one trainer for ten Marines on a virtual range versus one trainer for each Marine on the LF range. Company owner Jody Scheckter stated to the *Atlanta Constitution* that, "We were in the right place at the right time with peace dividend and with everyone having less money" (Kelly, 1997, p. 3A). He explained that "They save money by training for less." Training for less is what the USMC has sought to do. The "peace dividend" Scheckter spoke of is the redirection of funds saved by using the ISMT.

E. STUDY OBJECTIVES

Do these high-fidelity interface devices (locomotion devices or immersive displays) contribute enough to training effectiveness to justify their cost? In addition, the availability and presumed widespread use of video and computer games by Marines have created interest in the use of either commercial or specially-designed games to meet some part of the military's training needs. Can the ISMT provide the Marine Corps Recruit the required basic rifle training at a fraction of the cost?

The data presented will indicate whether the use of modern virtual trainers, such as the ISMT, will reduce the overall expenditures of the Marine Corps Recruit Basic Marksmanship Training over ten year periods. Costs will be compared for the live-fire training (LFT) events performed at Camp Pendleton in California with the combination

of the ISMT system with LFT for the same training. This research will also identify whether the use of ISMT with LFT, is as effective a means to train Marine Corps marksmen, as LFT alone.

The hypothesis is that the ISMT system will prove to be less expensive over the years that it is in use to replace LF ranges. Additionally, ISMT coupled with LFT will be as effective for marksmanship training as using LFT alone for marksmanship training.

F. ORGANIZATION OF THE MBA PROJECT

This Project is organized in the following chapters:

Chapter I: Introduction. Discusses the basics of what training is required by the Marine Corps and the options to achieve the training objectives.

Chapter II: Background. Introduces the history of the rifle as well as the origins of virtual reality technology.

Chapter III: Methodology. Describes the relevant concepts used to analyze the cost and effectiveness of using the ISMT trainer as well as how the data were collected.

Chapter IV: Data Analysis. Discusses and analyzes the data collected for the project.

Chapter V: Conclusions and Recommendations. Provides recommendations for use of the ISMT, and guidelines for future research.

II. BACKGROUND

A. ORIGIN OF THE MODERN RIFLE

The earliest known written formula for gunpowder came from the Wujing Zongyao in 1044 AD (Chase, 2003). Written by Zeng Gongliang and Yang Weide of the Chinese Song Dynasty, the treatise was credited for changing the shape of modern warfare. Gunpowder was the first chemical explosive and the only one known until the invention of nitrocellulose, nitroglycerin, smokeless powder and TNT in the 19th Century. Prior to the invention of gunpowder, many incendiary and burning devices had been used. Gunpowder is considered one of four great inventions of ancient China.

According to Kelly (2004), around 1240, the Arabs acquired knowledge of saltpeter ("Chinese snow") from the East, perhaps through India. They learned about gunpowder and not long after were introduced to fireworks ("Chinese flowers") and rockets ("Chinese arrows").

Gunpowder or black powder is of great historical importance in chemistry. Although it can explode, it was used primarily as a propellant. Originally, it was made by mixing elemental sulfur, charcoal and saltpeter (potassium nitrate). Charcoal traditionally came from the willow tree, but grapevine, hazel, elder, laurel, and pinecones have all been used. Charcoal is not the only fuel that can be used as an explosive device. In many pyrotechnic applications, sugar is used instead of charcoal. When the ingredients were carefully ground together, the end result was a powder that was called “serpentine.” The ingredients tended to require remixing prior to use. As a result, gunpowder was very dangerous to make.

People who made gunpowder would sometimes add water, wine or another liquid to reduce the hazard of an explosion. However, a single spark could result in a smoky fire. Once the serpentine was mixed with a liquid, it could be pushed through a screen to make small pellets which were then allowed to dry. In firearms, black powder allows

loading by volumetric measure. Smokeless powder requires precise measuring of the charge by weight to prevent damage due to overloading. Damage by overloading is still possible with black powder.

In the 1300s, handguns from the Yuan dynasty were known to have tipped the scale in many battles. During the Chinese Ming Dynasty (1368-1644 AD), matchlock firearms were the preferred weapons of choice. However, the earliest surviving documented evidence for the use of the hand cannon, considered the oldest type of portable firearm and a forerunner of the handgun, are from several 14th Century Arabic manuscripts (Wuxia Society, n.d.).

Today, modern warfare relies heavily upon the foundation established in the early 11th Century for the defense of our nation—the rifle. The rifle has evolved into a formidable offensive instrument and a convincing deterrent against threats.

B. VIRTUAL REALITY HISTORY

The concept of virtual reality (VR) has been in existence for decades, even though the public really only became aware of it in the early 1990s. In the mid-1950s, a cinematographer named Morton Heilig envisioned a theatre experience that would stimulate audiences' senses, drawing them into the stories more effectively. He built a single-user console in 1960 called the Sensorama that included a stereoscopic display, fans, odor emitters, stereo speakers and a moving chair. He also invented a head-mounted display (HDM) designed to let a user watch television in 3-D. Users were passive audiences for the films, but many of Heilig's concepts would find their way into the VR field (Pimentel and Teixeira, 1993).

To fully understand what virtual reality is, we should first understand what normal reality is. Reality is the state of things as they actually exist, rather than as they may appear, or as they are thought to be (Pimentel and Teixeira, 1993). In its broadest definition, reality includes everything that is and has being whether it is observable or comprehensible. Virtual is a concept applied in many fields with somewhat differing connotations as well as denotations. According to Pimentel and Teixeira (1993), virtual

means “Almost or nearly as described, but not completely or according to strict definition: [e.g.,] the virtual absence of border controls.”

Virtual reality is the use of computer technology to create a simulated, three-dimensional world that a user can manipulate and explore, while feeling as if he were in that world. Scientists, theorists and engineers have designed dozens of devices and applications to achieve this goal. There have been different opinions on what exactly constitutes a true VR experience, but in general it should include the following attributes: (1) three-dimensional images that appear to be life-sized from the perspective of the user, (2) the ability to track a user's motions, particularly his head and eye movements, and (3) the ability to correspondingly adjust the images on the user's display to reflect the change in perspective (“Virtual,” n.d.).

C. VIRTUAL REALITY IMMERSION

In a virtual reality environment, a user experiences immersion, or the feeling of being inside and a part of that world. The user is also able to interact with the environment in meaningful ways. The combination of a sense of immersion and interactivity is called telepresence. Computer scientist Jonathan Steuer (1992) defined it as “the extent to which one feels present in the mediated environment, rather than in the immediate physical environment.” In other words, an effective VR experience causes the user to become unaware of real surroundings and focus on the existence inside the virtual environment, such as in a room on a virtual firing range.

Steuer (1992) proposed two main components of immersion: (1) depth of information and (2) breadth of information. Depth of information refers to the amount and quality of data in the signals a user receives when interacting in a virtual environment. For the user, this refers to such qualities as a display’s resolution, the complexity of the environment’s graphics, and the sophistication of the system’s audio output. Steuer (1992) defines breadth of information as the “number of sensory dimensions simultaneously presented.” A virtual environment (VE) experience has a wide breadth of information if it stimulates all of the senses. Most VE experiences

prioritize visual and audio components over other sensory-stimulation factors. A growing number of scientists and engineers are looking into ways to incorporate a user's sense of touch. Systems that give a user force feedback and touch interaction are called haptic systems.

For immersion to be effective, a user must be able to explore what appears to be a life-sized virtual environment and be able to change perspectives seamlessly. If the VE consists of a single pedestal in the middle of a room, a user should be able to view the pedestal from any angle and the point of view should shift according to where the user is looking. According to Meehan, Insko, Whitton & Broooks (2002)—researchers in VR technology and theory—displays must project a frame rate of at least twenty to thirty frames per second in order to create a convincing user experience.

D. VIRTUAL REALITY INTERACTIVITY

Immersion within a virtual environment is one thing, but for a user to feel truly involved there must also be an element of interaction. Early applications, using the technology common in VE systems today, allowed the user to have a relatively passive experience. Users could watch a pre-recorded film while wearing a head-mounted display (HMD). Users would sit in a motion chair and watch the film as the system subjected the user to various stimuli, such as blowing air on them to simulate wind. While users felt a sense of immersion, interactivity was limited to shifting their point of view by looking around. The user's path was pre-determined and unalterable.

Navigation within a virtual environment is one kind of interactivity. If a user can direct movement within the environment, it can be called an interactive experience. Most virtual environments include other forms of interaction, since users can easily become bored after just a few minutes of exploration. True interactivity also includes being able to modify the environment. A good VE will respond to the user's actions in a way that makes sense, even if it only makes sense within the realm of the virtual environment. If a VE changes in outlandish and unpredictable ways, it risks disrupting the user's sense of telepresence.

E. MILITARY TRAINING IN THE VIRTUAL ENVIRONMENT

From the earliest days in the history of VR, the United States' military forces have been a driving factor in developing and applying new VR technologies. Along with the entertainment industry, the military is responsible for the most dramatic evolutionary leaps in the VR field. Virtual environments work very well in military applications. When well-designed, they provide the user with an accurate simulation of real events in a safe and controlled environment. Specialized military training can be very expensive. Some training procedures have an element of danger when using real situations. While the initial development of VR gear and software is expensive, in the long run it is much more cost effective than putting a Marine onto a live-fire rifle range.

When engineers first began to experiment with head-mounted displays (HMDs), the military took notice. Both the Navy and the Air Force funded some of the earliest work in developing effective HMDs. The first HMDs were not linked to a virtual environment. Instead, they were linked to a camera. Engineers mounted a camera to a servo-controller. A user wearing the HMD could control where the camera pointed by turning his head in different directions. Currently, the military uses VR techniques not only for training, but also for safety enhancement as well as on the gun ranges. The interaction of humans and technology for the purpose of training requires an interface that links the human system and the computer system. This link is accomplished by using multimodal input.

Two major groups of multimodal interfaces have merged. The first group of interfaces combined various user input modes beyond the traditional keyboard and mouse input/output, such as speech, pen, touch, manual gestures, gaze, head and body movements. The most common of such interface combines a visual modality (e.g., a display, keyboard and mouse) with a voice modality (speech recognition for input, speech synthesis and recorded audio for output). Other modalities, however, such as pen-based input or haptic input/output may be used. Multimodal user interfaces are a research area in human and computer interaction (HCI).

F. MARINE CORPS MARKSMAN

In the very early years of warfare, especially naval warfare, there was little difference between sailors and soldiers deployed on warships. All of the crew had to be capable of fighting opposing ships' crews in hand-to-hand combat ("Birth of Marines," n.d.). The first organized Corps of Marines was created when Charles V first assigned the naval infantry of the Compañías Viejas del Mar de Nápoles (Naples Sea Old Companies) to the Escuadras de Galeras Del Mediterráneo (Mediterranean Galley Squadrons) in 1537, progenitors of the current Infantería de Marina Corp ("Historia," n.d.).

Many people would argue that the one hallmark of the Marine Corps is that every Marine is a rifleman regardless of Military Occupational Specialty (MOS). Throughout their history, riflemen of the United States Marine Corps have proven themselves time and time again in their shooting prowess. However, to attain and continue their lethality, Marine riflemen must learn and practice marksmanship skills. The perishable and deadly skill of shooting is one of the first basic techniques of combat that a Marine rifleman learns. Marines spend several weeks of range time in the beginning of their training for marksmanship skills. They have done so since the Corps' inception in the late 17th century.

On November 9, 1775, the Second Continental Congress convened to discuss sending an amphibious expedition to Halifax in Nova Scotia ("Resolution," 1775). After launching two land expeditions toward the St. Lawrence River months earlier, Richard Montgomery's and Benedict Arnold's forces were each making their way toward Quebec City to join forces. Congress was convinced that sending Marines to fight at sea and engage military operations ashore was the primary key in destroying an important British naval base in Halifax. On November 10, 1775, Congress directed the Naval Committee to raise two Marine battalions at the Continental Congress' expense. Also, Congress decided that the Marines would be used not only for the Nova Scotia expedition, but for subsequent service thereafter. The Naval Committee established a network of

appointments for offices that included a paymaster, commissions, procurement, and equipment for establishing a future National Corps of Marines.

The United States Marine Corps still celebrates November 10 as its official birthday. Borrowing from the British Royal Navy, the practices and printed instructions were outlined in the "Rules for the Regulations of the Navy of the United Colonies." It was intended that the American Marines would provide the same services as British Marines. The two battalions of Continental Marines officially became "resolved" when Congress issued the first commission to Captain Samuel Nicholas on November 28, 1775. Nicholas' family members were tavern keepers. His prominence came not from his work, but from his leadership in two local clubs—for foxhunters and sport fishermen. Historian Edwin Simmons surmises that Nicholas was most likely using his family tavern, the "Conestoga Wagon," as a recruiting post. However, the standing legend in the United States Marine Corps today places its first recruiting post at Tun Tavern ("United States Marine Corps," n.d.).

G. WHY MARINES TRAIN FOR MARKSMANSHIP

According to Yates (2004):

> The presence of highly skilled marksmen has been the decisive factor in many small unit engagements. The employment of snipers against enemy forces in many cases has a disproportionate impact in a battle. These expert marksmen engage the enemy in a manner that can almost be described as asymmetric because the enemy cannot respond in kind to counter a sniper's attack. (p. 8)

The development of highly skilled shooters to be able to counterbalance an enemy's advances is one of the primary purposes of the Marine Corps' marksmanship training. Training aids are used to advance the Marine from a novice, even timid, carrier of a lethal firearm to a carrier of a deadly weapon of war. Training aids such as the ISMT are used to adapt the fundamentals a Marine has learned in training to a combat environment.

The Marine Corps has an order called the Marine Corps Combat Marksmanship Programs. The Marine Corps Order (2007) states:

> The Marine Corps' primary mission is to locate, close with and destroy the enemy by fire and maneuver and to repel assault by fire and close combat during amphibious assaults and subsequent operations ashore. Combat ready Marines must be skilled in tactics and highly proficient in the use of firearms. Well-trained Marines have the confidence required to deliver accurate fire under the most adverse battle conditions. The rifle is the primary means by which Marines accomplish their mission. (Marine Corps Order, 2007)

The order "establishes Marine Corps policy and prescribes requirements governing the Marine Corps Combat Marksmanship Program to include initial qualification and annual re-qualification with the service rifle" (Marine Corps Order, 2007).

H. MARKSMANSHIP RANGE TASKS

During the thirteen-week recruit training, commonly known as "Boot Camp," every Marine must go through the basic marksman training phase. Boot camp is broken down into three phases. Each phase has a certain number of training days. Marksmanship is taught in the second week of phase two, also known as "Grass Week." Part of this week is spent in the classroom learning about basic rifle marksmanship and the M16A2. The other part is spent actually holding a rifle and practicing firing positions, known as "snapping in." This instruction is given by the Primary Marksmanship Instructor (PMI), a Marine with the MOS 0931. The third week of the second phase of training is "Firing Week," which ends in the Qualification Day.

Firing Week is broken down into five days. Each day consists of a set of tasks known as "tables." There are four tables of fire and a preparatory training event prior to beginning Table 1. Tables are designed to incrementally take the Marine through a prescribed set of firing standards in different firing positions to familiarize the rifleman with the different forms of combat positions. Each table has a set number of rounds to be shot in a sequential manner, and an optimal time to shoot (Marine Corps Order, 2007). On day 5 of Firing Week, each Marine will fire a qualification round and earn a qualification badge.

Table 1 is Fundamental Rifle Marksmanship (FRM). The purpose of this table is to learn the fundamental knowledge, skills and attitudes necessary for the safe and accurate firing of a rifle. The information covered in this stage of training will form the basis for all other training with the rifle. Marines are evaluated on their mastery of FRM skills during Table 1's course of fire (Appendix A).

Table 2 is Basic Combat Rifle Marksmanship (BCRM). BCRM is the first step in transitioning a Marine from fundamental marksmanship to becoming a proficient combat marksman. Marines are evaluated on their mastery of BCRM skills at the completion of Table 2 training (Appendix B).

Table 3 is Intermediate Combat Rifle Marksmanship (ICRM). ICRM reinforces and improves basic combat shooting skills and introduces additional techniques and procedures. Upon completion of ICRM, the Marine has demonstrated the required skills for successful completion of the tasks assigned to the Marine rifleman. He is satisfactorily prepared for additional mission-specific rifle training as determined by his commander. To this end, modular attachments such as rifle combat optic and night aiming devices will be introduced (if available to the unit) during this stage of training.

Table 4 is Advanced Combat Rifle Marksmanship (ACRM). ACRM reinforces and improves combat shooting skills and introduces advanced techniques and procedures relevant to the infantry Marine. Upon completion of ACRM, the Marine has demonstrated the required skills for successful completion of the rifle tasks assigned to the infantry Marine. The Marine is prepared for additional infantry-specific rifle training as determined by his commander. Advanced techniques for modular attachments, such as rifle combat optics, night aiming and night vision devices, are continued and improved upon during this stage of training.

I. M16A2

For more than thirty years, the United States Marine Corps has used the M16 carbine rifle as its chosen standard weapon. The rifle is able to stand up to the demands of combat infantry. It can be used to make litters as a lifting device to carry wounded

Marines up a hill or over a short wall. The rifle can pound stakes into the ground when a proper tool is not available. Of course, the most common use of the rifle is for shooting. The rifle works well in jungles, deserts, and cold weather with minimal upkeep. Maintenance consists of properly cleaning the rifle, which should take only a couple of hours after extensive shooting. The Marine is trained to consider this weapon an extension of oneself; he (or she) learns to carry it everywhere and maintains the weapon-even when proper hygiene is not available for the Marine.

The M16A2 service rifle is a lightweight, magazine-fed, air-cooled, gas-operated and shoulder-fired weapon. This rifle is capable of firing either semi-automatic or three-round bursts (Venola, 2005). All of this information is burned into the rifleman's head during Boot Camp and in other supporting infantry schools.

The primary function of this weapon is for infantry support during combat. The FN Manufacturing LLC and Fabrique Nationale Manufacturing Incorporate mass-produce these weapons for the United States and many other foreign national militaries around the globe. The weapon weighs 8.79 pounds with a full loaded 30-round ammunition magazine inserted. It has a maximum shooting range of 2,624 feet and can fire up to 800 rounds per minute. This weapon costs the military approximately $586 per unit.

J. MEGGITT TRAINING SYSTEMS ISMT TRAINER

Meggitt Training Systems—originally Fire Arms Training Systems Incorporated (better known as FATS)—was incorporated in 1984. The company provides weapons training for many of the United States government and non-governmental agencies operating in and out of the country today. The military became interested in this company in the 1980s. In particular, the company is known for its ability to utilize simulation for "users to train in highly realistic situations through the integration of video and digitized projected imagery and modified, laser emitting firearms that retain the fit, function and feel of the original weapon" (Meggitt Training Systems, n.d.).

Meggitt Training Systems uses computer technology and provides an interactive live-fire simulation for its users. The technology uses film that simulates a very life-like backdrop for the simulation experience. Those who are immersed in the simulation performing various firing exercises feel as though they are in a real-world scenario. The simulators are typically used in darkened studios, and the images are projected onto screens simulating a variety of landscapes and battlefields.

The Meggitt Indoor Simulated Marksmanship Trainer (ISMT) is the keystone system that revolutionized the way Marines are trained and will continue to be trained. The ISMT's simulations system supports both individual and collective training in the use of a variety of weapons throughout the entire spectrum of military operations. Individual training consists of marksmanship training. A single system supports five individual firing lanes and can be networked together with additional systems for up to fifteen individual firing lanes. Each training system comes pre-loaded with standard sets of courseware to support training without any authoring (software writing) required (Meggitt Training Systems, n.d.).

K. RELEVANT STUDIES

Yates' (2004) thesis, "A Training Transfer Study of the Indoor Simulated Marksmanship Trainer," examines the effectiveness of the ISMT as a tool to train shooters in the fundamentals of marksmanship. Key concepts explored in the thesis are verification of transferred skills resulting from practice, and the predictive value of simulated performance with regard to proficiency at real task performance. Yates (2004) conducted two sets of experiments.

In the first set of experiments, he found that there was no statistical difference in the scores of recruits trained in the ISMT plus live-fire qualification, versus a control group that trained only on a conventional firing range followed by qualification. Furthermore, Yates (2004) made it clear that the ISMT test group fired part of the time under adverse weather conditions, but the control group did not. According to a statement from the PMI—included in the 2004 thesis—the control group fired under good weather

conditions. Under weather conditions equivalent to those faced by the control group, the ISMT test group might well have performed better than the control.

Yates (2004) observed:

> The comparison of the record score performance of the test and control groups indicates with a 95% confidence interval there is no statistical difference in the performance of those subjects who received training in the ISMT prior to live fire marksmanship training and testing for proficiency. Thus, we fail to reject the null hypothesis that subjects trained in the ISMT do not perform better than those who are trained without exposure to the ISMT. (p. 51)

The ISMT, however, was not found to be a standalone trainer that would eliminate the need for expert instruction and live-fire training:

> In a second experiment, subjects were evaluated on their proficiency and improvement during uncoached practice at the task of simulated precision fire on a target at a simulated known distance of 300 yards from the shooters. After comparable amounts of practice in the ISMT, subjects who had not previously received formal marksmanship training failed to demonstrate levels of proficiency comparable to those subjects who had previously received formal marksmanship training in the military. Consequently, the research found no evidence to suggest the ISMT qualifies as a black box training apparatus capable of imparting skill through practice without the added presence of expert instruction or an existing knowledge of marksmanship techniques. (Yates, 2004, abstract)

The Modeling, Virtual Environments and Simulation (MOVES) Institute at the Naval Postgraduate School in Monterey, California has been researching the ISMT for a number of years. The purpose for the experimenting is to enhance the operational effectiveness of the joint forces and allies. MOVES Institute is involved in many different experiments studying cognitive, psychomotor and affective attributes of training with the ISMT system (Ciavarlli, 2010).

Another aspect of the MOVES Institute is to study the Moving Target Engagement Trainer. The Institute is investigating the ability to train Marines to better shoot moving targets through the use of an intelligent tutoring system and the ISMT (MOVES Institute, 2010). MOVES Institute has been using the ISMT to analyze the

effectiveness of the potential replacement of live-fire training evolutions. Some of the data gained in the analysis of the hypothesis of this MBA project have come from the MOVES Institute (Ciavarlli, 2010).

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III. METHODOLOGY OF EXPERIMENTS

A. COST ANALYSIS OF SYSTEMS USED

1. Purpose

The intent of the cost analysis is to determine the financial advisability of using the ISMT in basic marksmanship training versus using live-fire training alone. This study will focus on the M16A2 service rifle and the simulated and live-fire equipment, supplies and logistical support for training with this weapons system. The question to be answered is: "Will using the ISMT for the M16A2 service rifle, instead of live-fire ranges for basic marksmanship training, eventually save the Marine Corps significant money?" The null hypothesis states that there would be little quantifiably significant savings if the ISMT system were to supplement live-fire ranges for basic marksmanship training, versus using live-fire training alone.

2. Evaluating the Investment

Most of the cost data obtained for use in this analysis were obtained from the Program Manager for Training Systems (PMTRASYS), U.S. General Services Administration Advantage website, and Meggitt Training Systems.

PMTRASYS is:

> the Marine Corps Systems Command's independent program manager (PM) whose responsibility is to provide services and products to support the development and life cycle support of USMC training and training systems. PMTRASYS provides various types of training analyses including Manpower and Training Analyses in support of Marine Corps Systems Command acquisition programs. (Marine Corps Systems Command, n.d.)

GSA Advantage is the government's premiere online shopping system. GSA Advantage provides instant access to millions of high quality products, services and

solutions from thousands of approved commercial vendors (GSA Advantage, n.d.). "Meggitt Training Systems, part of the Meggitt Defense Systems, provides Training Systems and Defense Systems used by militaries and law enforcement and security agencies around the world" (Meggitt Training Systems, n.d.). They develop, manufacture, market and service high-quality virtual training capabilities and live-fire training systems.

The financial case for the ISMT Mobile Military Trainer Simulation System (MMTSS) will be evaluated on the principles of net present value (NPV).

The Defense Acquisition University defines Life Cycle Cost as the total cost to the government over the lifetime of a defense acquisition program. The life cycle cost of a defense acquisition program typically consists of the following components:

- Research and Development;
- Procurement;
- Operations and Support (O&S); and
- Disposal.

For the purpose of this analysis, the disposable costs are assumed to be negligible with respect to the other three cost components over the lifetime of the system ("Using Net Present Value," n.d.).

The NPV of the investment is given by: $NPV = \sum_{t=0}^{n} \frac{CF}{(1+K)t}$

where:

n = time horizon of the cash flow

k = discount factor

CFt = net cash flow in time period t

The following assumptions are made for the baseline scenario:

- R&D has been completed and all costs associated are "sunk costs."
- The equipping scale is one site, and procurement will start immediately once the MBA project is completed.
- O&S costs are part of the initial contracted costs of the system.

- The system has a ten-year life cycle.
- Training will be two weeks long. This means that there are 26 batches of recruits annually.
- The training capacity of the ISMT Mobile Military Trainer Simulation System is a least equal to the current live-fire range training capacity.
- The length of time spent in ISMT is proportional to that of the live-fire ranges.
- Discount factors of 0%, 3%, 5% and 7% are compared.

B. EFFECTIVENESS ANALYSIS OF SYSTEMS USED

1. Purpose

The intent of this analysis is to determine if it is cost effective to use the ISMT in basic marksmanship training versus using only the live-fire training obtained on ranges at the Marine Corps Air Station Camp at Pendleton. This study will only deal with the M16A2 Service rifle, simulated and live-fire equipment, supplies, and logistical support for training with this weapons system. The question to be answered is whether the use of the ISMT system, coupled with LFT, is a more cost-effective means of training for basic marksmanship with the M16A2 service rifle, than the use of LFT alone.

The findings from Yates' (2004) thesis suggest that there will not be a significant reduction in training standards or marksmanship scores by using the ISMT before live-fire range training. Therefore, an appropriate mix of ISMT with live-fire range training should not reduce the overall effectiveness of the Marine Corps' basic marksmanship training standards.

2. Simulator and Subjects

The ISMT system utilized for this analysis was the Mobile Military Trainer Simulation System from the Meggitt Training Systems. This military trainer supports both individual and unit training across the entire spectrum of military operations. A single screen system provides a ten-foot-wide visual field. Each system includes eight

weapon ports for use with either tethered or Blue Fire (wireless) weapons. The system can network with one or two additional systems to form a Small Unit Trainer. The MMTSS has the appropriate materials to support training in marksmanship preloaded for the course of fire.

Marksmanship training encompasses short- and long-range stationary targets. The system includes robust editing for use by the instructor wanting to build unique and unit-specific training scenarios. According to MTS, the MMTSS provides an accurate simulation of weapon ballistics including the effects of wind speed and direction. Weapon aim point trace, shot location and the number of rounds fired are measurements that are identified in the shot feedback screen display. Barrel positions, muzzle trace, trigger pull and butt pressure are measured and monitored in real time for the training instructor (Meggitt Training Systems, n.d.).

The feedback from the ISMT during the course of this experiment by Yates (2004) consisted of several graphical task performance displays. The most basic feedback was the computed point of impact of the recruit's simulated round fired. The ISMT is capable of accurately displaying the point of aim to a precision of two minutes of angle. At the distance of approximately 240 inches from the muzzle of the SRS (and the hit sensor camera) to the projection screen, the point of impact is accurate to a distance of approximately 0.14 inches [sin (2/60) * 240" = 0.1396"] on the projection screen which is slightly larger than one-half of a 5.56mm bullet's diameter (Yates, 2004).

The analysis and selection of the test subjects were conducted in a previous experiment which evaluated the effectiveness of the ISMT training system on novice shooters. The test and control groups for this experiment consisted of one platoon each of male Marine Corps recruits who were undergoing initial marksmanship training at Edson Range on the Camp Pendleton Marine Corps Base in California. The platoon was randomly selected, based upon the attributes of its members, and their composition was a cross-sectional representation of the Marine recruits. According to the experiment, the subjects were selected based on a set of aggregate characteristics of the Marine recruits trained at Camp Pendleton.

All of the Marines were from the United States, west of the Mississippi River. They were segregated by sex during the initial entry-level training. During the initial entry-level training, all of the female Marines were trained at the east coast Marine Corps Recruit Depot located in Parris Island, South Carolina. The mental aptitude of the Marines was measured using the Armed Services Vocational Aptitude Battery (ASVAB). The ASVAB scores of the recruits in the test and control groups were not collected for the purposes of this experiment. Rather, the random nature of selection and the sample size of the groups provided a high statistical likelihood that the test and control groups mirrored the aggregate mental aptitude characteristics of all Marine recruits. The educational background of the test and control groups was recorded in the pre-training questionnaire and should be representative of the aggregate for all Marine recruits (Yates, 2004).

The physical size of the Marines who participated in the experiment was of interest because of the potential differences in performance based on their size relative to the M16A2 rifle. It is possible that the effectiveness of the ISMT might be diminished for recruits with longer reach because of the positioning of the telemetry cable on the fore stock of the Service Rifle Simulator (SRS). According to Yates (2004), the position of the telemetry cable may impede the natural positioning of the forward hand on the SRS, resulting in an uncomfortable shooting position that detracts from task performance (shooting accuracy).

3. Live Firing Versus ISMT

Live firing generally occurs in the fourth week of the Marine Corps' recruit training, more commonly known as "Boot Camp." This time is allotted for the Marine's basic marksmanship training on the live-fire ranges as well as classroom training on marksmanship theory and weapons care. The Marines are only given two weeks between weeks three and seven to develop into effective M16A2 practitioners. However, the rifle

training is designed not only to teach the novice marksman how to be a better manipulator of the M16A2 rifle, but also how to develop a combat mindset and become a confident rifleman.

Confidence is also developed as a result of marksmanship training. Believing in one's ability to engage targets accurately in any combat situation comes from consistent practice and positive reinforcement. The level of confidence a Marine develops is rooted in his (or her) belief that future challenges can and will be overcome, especially those challenges of firing well-aimed shots in a combat environment where the enemy will someday be returning fire. It is presumed that a factor in a Marine's level of confidence is the degree to which he has mastered the procedures and methods of the rifle marksmanship. The quality of instruction is the only way a Marine can master rifle marksmanship. The foundation of the marksmanship fundamentals is developed during those two very important weeks of practical application during the range and field firing trainings.

This fact speaks directly to the impact that the ISMT system can have on the trainee. The ISMT is specifically designed to simulate real time scenarios that mimic strenuous live-fire environments without sacrificing training that may have occurred on a live-fire range. The effectiveness of the ISMT combined with LFT was proven through Yates' (2004) experiment to be equally effective if not more effective than LFT alone, because of the trainer's ability to retrain students rapidly. If a trainee requires more training or time to become more confident with the rifle, a simple push of a button allows the Marine to reset and reengage targets quickly.

The first week of training is commonly referred to by the Marine Corps as "Grass Week." This is the time when Marines sit in classrooms for lectures on basic rifle procedures, safety procedures and weapon make-up, as well as dry firing of the weapon to get accustomed to the feel of the rifle. The second week is when the Marines, for the first time, have the opportunity to fire the M16A2 service rifle on a live-fire range.

In the experiment conducted by Yates (2004), the test and the control groups separated their course of instruction on the final two days of "Grass Week." Normally,

these days of training included combinations of classroom instruction as well as practical applications. This application portion of the training was a combination of simulation training on the ISMT and "snapping in." "Snapping in" is where a recruit assumes the proper shooting position with an unloaded rifle aimed at a target and simulates firing at the target by pulling the trigger ("dry firing"). "Dry firing" refers to the act of actuating the trigger with no ammunition loaded into the weapon. Instead of a recruit in the test group "snapping in," the Marine is immediately placed into the ISMT simulator and allowed to begin his marksmanship training on a simulated known distance (KD) range.

4. Manipulated Guidelines

a. Training Organization

The training Marines in the control group received in accordance with the Yates' experiment deviated slighted from the Standard Operating Procedure (SOP) set in place by Marine Corps Order 3574.2K, Marine Corps Combat Marksmanship Program. The Marines were not allowed any contact with the ISMT trainer, and reverted to the same training cycle the Marine Corps had been following prior to contracting the Meggitt Training Systems ISMT trainer. The course of instruction for the test group meant firing as many rounds as possible on the ISMT during the final two days of "Grass Week," with the total training time being nine hours. The ISMT used during the final two days of training for the test group was capable of training 18 different Marines on 18 separate firing ranges while another 18 Marines observed. For the purposes of Yates' (2004) experiment, he considered this ISMT arrangement able to train 36 recruits. The final outcome of training at the end of "Grass Week" resulted in 36 out of 55 Marines in the test group being trained and assessed in the exact same course of fire as the live-fire-trained Marines. Thus, all outcomes drawn from the live-fire-trained Marines and the ISMT-trained Marines are not biased by any difference in the training that they received.

5. Marksmanship Technician

The Primary Marksmanship Instructor (PMI), as previously stated, was essential in laying the foundation for the test and control groups' marksmanship training. It was previously determined that the same instructor be used throughout the entire course of instruction during the experiment for both the test and the control groups. The minimization of any confounding variable that may have caused variations in the data collected was one of the main reasons a single instructor was chosen to train both sets of Marines. However, the change in SOP did add one confounding variable to Yates' experiment: a delay in training for one of the groups in the experiment. The group had to wait three additional weeks before live-fire qualification training due to the extra time needed to separately train the test group on the ISMT by the single instructor.

IV. DATA ANALYSIS

A. ANALYSIS OF EFFECTIVENESS OF ISMT

Yates' (2004) thesis, "A Training Transfer Study of the Indoor Simulated Marksmanship Trainer," spelled out in a compelling manner that without confounding variables which may have biased groups being tested, the ISMT might be as effective an initial trainer as live-fire ranges alone before qualifying on the M16A2. His summary of the data compiled show that the test group and the control group involved in his experiment show scores that are very similar. Figure 2 is a summary statistic box plot that shows the scores recorded by the ISMT shooters (test) group as compared to the live-fire range shooters (control group) on qualification day.

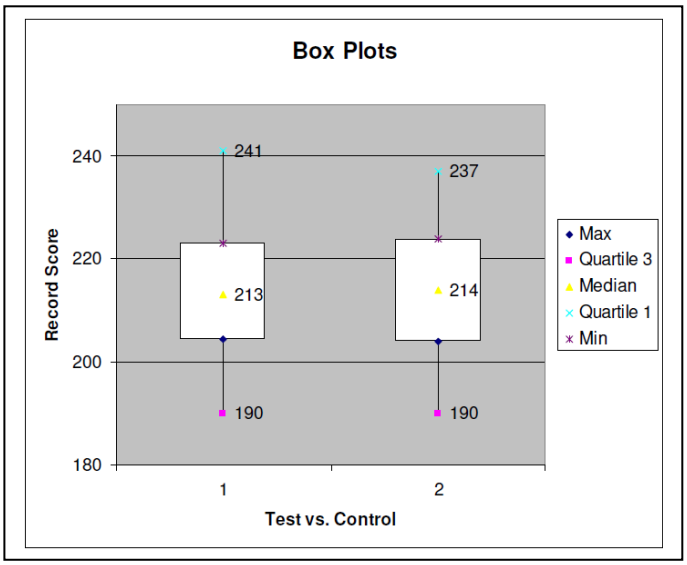

Figure 2. Mean Scores of Test Versus Control Groups

Per Marine Corp Order MCO 3574.2J written before 2007, KD courses of fire for new Marine recruits rifle training have very specific standards for qualification. The qualifying scores have minimum, maximum, and average ranges of scores that are broken down into ranked classifications (Marine Corps Order, 2007). The maximum range of

scores is 220–250 points, and classifies a Marine as an Expert Marksman. The average range is 219–210 points, which classifies a Marine as a Sharpshooter. The minimum range of score is 190-209 points, which classifies a Marine as a Marksman.

Yates (2004) further broke out the experiment results in Figures 2, 3, and 4 of his thesis. Figure 2 is a histogram showing the distribution of the test group's recorded score during his experiment. Figure 3 is a histogram showing the distribution of the control group's recorded score during his experiment. Figure 4 is a table showing the summary of performance of the two groups. Figures 2 and 3 are both histograms that plot on the X axis the points scored and on the Y axis number of shooters earning that particular score.

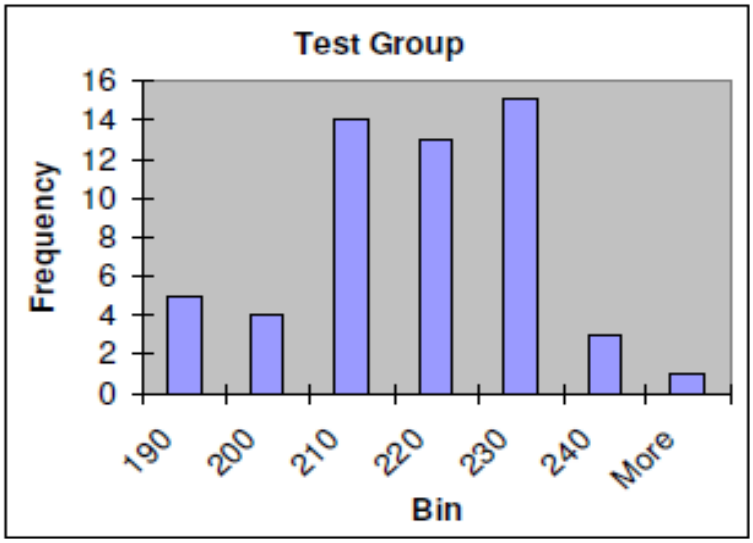

Figure 3. Distribution of Test Group Scores

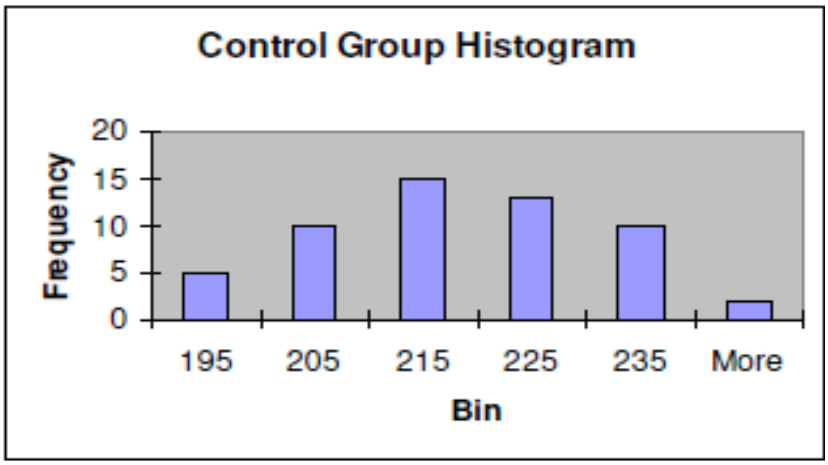

Figure 4. Distribution of Control Group Scores

	Test	Control
Marksmen	22	20
Sharpshooters	13	15
Experts	20	20
Median	213	214
Mean	212.96	213.29
Standard Deviation	13.31	12.44
Below –s	9	10
Above +s	12	12

Table 1. Test and Control Group Shooting Statistics

Both the test and control groups had shooters that failed to qualify on their initial attempts. All of these shooters were given the opportunity to repeat the course of fire until they attained the minimum score required to become a Marksman. The test group in Yates' experiment had three fail the initial qualification and the Control Group had two fail the initial qualification. In each case, the shooters shot again and attained a passing score to qualify. In each representation of the results of the experiment, it is clear that both the test group and the control group qualified 100% of the shooters in the experiment.

An excerpt from Yates' (2004) thesis states:

> The comparison of the record score performance of the test and control groups indicates with a 95% confidence interval there is no statistical difference in the performance of those subjects who received training in the ISMT prior to live-fire marksmanship training and testing for proficiency. Thus, we fail to reject the null hypothesis that subjects trained in the ISMT do not perform better than those who are trained without exposure to the ISMT. The lack of significant difference between the test and control groups does not assume that dry fire training during grass week, whether in the virtual environment of the ISMT or not, is a strong predictor of live-fire performance. (p. 51)

B. ANALYZING COST OF ISMT VERSUS COST OF LIVE-FIRE RANGES

In this data analysis, the life-cycle costs, specifically, those associated with personnel, live-fire operations, and ISMT operations, are examined.

1. Personnel Costs of ISMT Versus Live-Fire Ranges

Personnel costs consist of the estimated cost of the required manning levels to conduct safe range firing. These costs typically include total salaries of personnel included in the evaluation, broken down into hours.

2. Operations and Support Cost for a Live-Fire Range

Live-fire range operation costs consist of the estimated cost of operating and supporting live firing on the range, including all direct and indirect costs incurred while using this particular training method. Operations and support (O&S) cost is the recurring cost incurred to maintain the operational readiness of the live-fire range throughout its life cycle.

3. Operations and Support Cost for ISMT

ISMT operation costs consist of the estimated cost of operating and supporting fielded systems, including all direct and indirect costs incurred while using this particular training method. Operations and support cost is the recurring cost incurred to maintain the operational readiness of the system throughout the life cycle of the ISMT system.

4. Baseline Costs

All baseline costs are provided in thousands of dollars in fiscal year (FY) 2011. The data were gathered from the live-fire range and the fielded ISMT systems. Some basic assumptions had to be made in order to facilitate analysis of the data. They are detailed below:

- No research and development (R&D) cost was required for analysis
- No procurement cost was required for analysis
- Live-fire range requires 1 range coach per 5 shooters
- Live-fire range has 5 PMI's due to the safety concerns of firing on live ranges
- All ranges have 50 firing lanes to accommodate 1 company of Marines
- All ranges accommodate 24 classes per each with 6 companies of 50 Marines per company
- Each year, 144 classes shoot on each of the ranges
- Live-fire range makes up 70% of all range preventative maintenance costs due to prequalification by non ISMT shooting
- Live-fire range Marines are on range 8 hour per day
- Live-fire range time requires 4 days of prequalification followed by 1 day for qualification
- All non-commissioned officers (NCOs) and PMIs are E6 with 8 years of service
- All range coaches and bus drivers are E4 with 4 years of service
- All range safety officers are W2 with 12 years of service
- All recruit marksmen are E1 with less than 2 years of service
- Each ISMT shooter has 1 weapon
- Each ISMT lane has 1 spare weapon for a total of 10 spare weapons
- Each ISMT range has 1 PMI per 5 shooters for a total of 10 PMI's
- Discount factors used (0%, 3%, 5%, 7%)
- Time horizon is 10 years

- Qualification day is the same for ISMT and live-fire shooters on the range so costs are negated

The following tables are a collection of the initial data used to conduct the analysis.

All values are in FY11$K

YR	0	1	2	3	4	5	6	7	8	9	10
Personnel Cost	$0	$1,602k	$1,602k	$1,602k	$1,602k	$1,602k	$1,602k	$1,602k	$1,602k	$1,602k	$1,602k
ISMT Operation	$0	$45k	$45k	$45k	$45k	$45k	$45k	$45k	$45k	$45k	$45k
ISMT Initial Investment	$12,046k	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Revenue	$0	$0		$0	$0	$0	$0	$0	$0	$0	$0

Table 2. Personnel and Live-fire Operations Costs Over 10 Years

YR	0	1	2	3	4	5	6	7	8	9	10
Personnel Cost	$0	$3,076k	$3,076k	$3,076k	$3,076k	$3,076k	$3,076k	$3,076k	$3,076k	$3,076k	$3,076k
Live Fire Operation	$0	$1,308k	$1,308k	$1,308k	$1,308k	$1,308k	$1,308k	$1,308k	$1,308k	$1,308k	$1,308k
Revenue	$0	$0		$0	$0	$0	$0	$0	$0	$0	$0

Table 3. Personnel and ISMT Operations Costs Over 10 Years

5. Net Present Value (NPV)

The Net Present Value (NPV) of an investment is defined as the sum of the present values of the annual cash flows. The annual cash flows are the Net Benefits (revenues minus costs) generated from the investment during its lifetime. These cash flows are discounted or adjusted by incorporating the uncertainty and time value of money. NPV is calculated as follows (12).

$$NPV = \sum_{t=0}^{n} \frac{CF}{(1+K)t}$$

where:

t = the time of the cash flow

n = time horizon of the cash flow

k = the discount rate

CFt = net cash flow in time period t

In this analysis, there is no revenue generated; therefore, the investment (savings) will be calculated as the total price difference between the live-fire range operations minus the ISMT range operations and the investment is equivalent to the NPV of cost savings.

Discount rate is the rate used to discount future cash flows to their present values. An approach to choosing the discount rate factor is to decide the rate, which the capital needed for the project, could return if invested in an alternative venture (Venola, 2005). Discount rates of 0%, 3%, 5%, and 7% were analyzed.

C. TEN-YEAR COMPARISON OF ISMT RANGE VERSUS. LIVE-FIRE RANGE

The following tables are illustrations of NPV at 0%, 3%, 5%, and 7% discount factors over a 10-year time horizon. Each of the two firing range options are compared against each other, and based upon the NPV, a choice of which range is most suitable for cost savings for the USMC is made.

1. Financial Metrics (10-Year time horizon)

NPV SAVINGS FINANCIAL METRICS		
TOTAL NPV @ 0% (NPV OF LF MINUS NPV OF ISMT)	**$ 17,109,026.35**	**POSITIVE = GOOD**
TOTAL NPV @ 3% (NPV OF LF MINUS NPV OF ISMT)	**$ 12,734,376.27**	**POSITIVE = GOOD**
TOTAL NPV @ 5% (NPV OF LF MINUS NPV OF ISMT)	**$ 10,334,417.09**	**POSITIVE = GOOD**
TOTAL NPV @ 7% (NPV OF LF MINUS NPV OF ISMT)	**$ 8,266,055.44**	**POSITIVE = GOOD**

Table 4. 10-year NPV Savings Financial Metrics of LF Versus ISMT range

Table 2 shows the total NPV saving of using the ISMT versus the live-fire ranges, assuming four different discount factors. The 0% discount factor yields the highest NPV savings and the 7% discount factor yields the lowest NPV savings. Of the two ranges, the ISMT range operations provides the highest NPV savings over periods 0-10 from 0%, 3%, 5%, and 7% discount factors. There may be a mix of LF training and ISMT training in future marksmanship training events. This study identifies the cost savings potential if that mixture of the two training events takes place.

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V. CONCLUSION AND RECOMMENDATIONS

This project was designed to research the current and historical use of USMC marksmanship training. Cost analysis data for the effective use and application of the ISMT were analyzed and presented. The data showed cost comparisons of using live-fire training versus ISMT for Marine marksmanship training as well as the effectiveness of using the ISMT systems training. The questions that were researched are:

- Can the use of ISMT reduce Marine Corps training costs compared to using live-fire ranges?
- Will continued use of the ISMT be as effective as live-fire rifle ranges?

The research identified current virtual training systems used by the USMC are just as effective as using live-fire ranges. Additionally, there exist significant savings opportunities by using the ISMT for Marine Corps marksmanship training.

A. COST-BENEFIT AND EFFECTIVENESS ANALYSIS

For the United States Marine Corps, the ISMT—coupled with live-fire training for initial recruits—is the best type of training, from a cost and effectiveness standpoint.

Table 5 illustrates the Total NPV of ISMT versus the Total NPV of LF at various discount factors over the 10-year time horizon for the USMC. The cost analysis shows the ISMT yields the highest Total NPV savings compared to live-fire range operations (without ISMT). Table 6 shows there is no significant difference in qualifications scores between the ISMT plus live-fire test subjects and the live-fire control group.

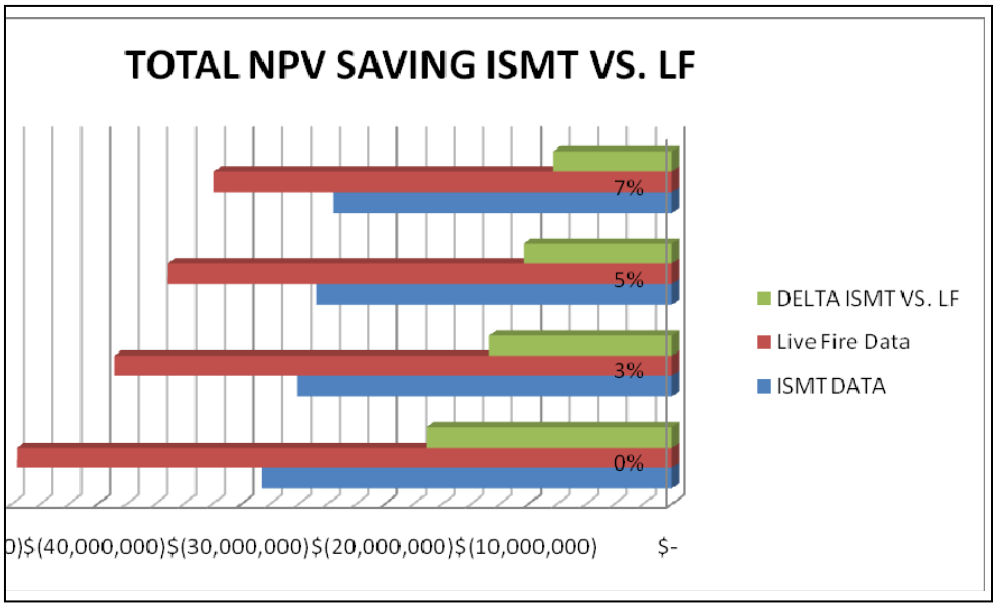

Table 5. Total NPV Saving: ISMT Versus LF

	Test	Control
Marksmen	22	20
Sharpshooters	13	15
Experts	20	20
Median	213	214
Mean	212.96	213.29
Standard Deviation	13.31	12.44
Below –s	9	10
Above +s	12	12

Table 6. Test and Control Group Shooting Statistics

B. THE DECISIVE POINT

The analysis in this project concluded that there is definitely a large potential to save money while having the same quality and robust training using the ISMT coupled

with LFT. This system, while providing a higher NPV, also provided the quality of training require by Marine recruit marksmen. The major costs associated with the determination are for the most part driven by the man hours used by live-fire ranges as well as the low life-cycle cost of the ISMT range.

Consideration should be given to the robust nature of technology development. Neither the 10-year life-cycle analysis, nor the cost data, account for the mid-life hardware and software upgrades that will be required to keep the ISMT system relevant. Such future upgrades have the potential to continue the trend of cost savings for the ISMT system. Cost avoidance for the Marine Corps suggests consideration of use of this system for primary marksmanship training prior to live-fire qualification.

C. RECOMMENDATIONS FOR FUTURE STUDIES

One topic for further study is the optimal amount of time Marines should spend on live-fire ranges versus in the ISMT prior to the qualification shoot. Live-fire ranges consistently cost more over time due to the safety concerns and the manpower required to address such concerns. It would be desirable to compare the quality of the range time and costs associated with live-fire training to that of ISMT training.

Alternate forms of training cycles should be identified for future training evolutions. The following should be considered:

- ISMT-only training;
- Mix of live-fire and ISMT training; and
- Organizing live-fire training such that it maximizes the Marines' time on the range (actual or virtual).

Additionally, future research should identify how much training would be required on the ISMT to have the best performance during the live-fire qualification shoot. Such research could lead to finding a balance of ISMT and LFT that maximizes the Marines' chances of attaining better qualification scores.

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APPENDIX A. COURSE OF FIRE FOR TABLE 1 (FUNDAMENTAL RIFLE MARKSMANSHIP)

Entry Level Preparatory Training

	Distance	Target	Time (sec)	Rounds	Position	Sling
Grouping	36 yds	BZO	60	5	Prone	3pt / Loop
Exercise	36 yds	BZO	60	5	Prone	3pt / Loop
	36 yds	BZO	60	5	Prone	3pt / Loop

Prior to beginning training on Table 1 of the Marine Corps Combat Rifle Program, shooters must complete Preparatory Training. The following Individual Training Standards (ITS) are introduced at the Entry Level Sites.

a. 0300.M16.1001 Perform weapons handling procedures with a service rifle/carbine.

b. 0300.M16.1002 Maintain a service rifle/carbine.

c. 0300.M16.1003 Perform corrective action with a service rifle/carbine.

d. 0300.M16.1004 Zero a service rifle/carbine.

a. Tri-Fire (Day 1)

	Time (min)	Distance (yards)	Target	Rounds	Position	Sling
Tri-fire	1	200	"A"	3	Sitting	3pt / Loop
(Day 1)	1	200	"A"	3	Sitting	3pt / Loop
	1	200	"A"	4	Sitting	3pt / Loop

b. Table 1 Training (Days 1-3)

	Drill	Time (min)	Distance (yards)	Target	Rounds	Position	Sling
Stage One	Slow Fire	25	200	"A"	5	Sitting	3pt / Loop
			200	"A"	5	Kneeling	3pt / Loop
			200	"A"	5	Standing	Parade
Stage Two	Rapid Fire	1	200	"D"	10	Standing to Sitting	3pt / Loop
		1	200	"D"	10	Standing to Sitting	3pt / Loop
Stage Three	Slow Fire	5	300	"A"	5	Sitting	3pt / Loop
Stage Four	Rapid Fire	1	300	"D"	10	Standing to Prone	3pt / Loop
		1	300	"D"	10	Standing to Prone	3pt / Loop
Stage Five	Slow Fire	15	500	"B-MOD"	10	Prone	3pt / Loop
				Total	70		

c. Table 1 Pre-Evaluation/Evaluation (Days 4-5)

	Drill	Time (min)	Distance (yards)	Target	Rounds	Position	Sling
Stage One	Slow Fire	20	200	"A"	5	Sitting	3pt / Loop
			200	"A"	5	Kneeling	3pt / Loop
			200	"A"	5	Standing	Parade
Stage Two	Rapid Fire	1	200	"D"	10	Standing to Sitting	3pt / Loop
Stage Three	Slow Fire	5	300	"A"	5	Sitting	3pt / Loop
Stage Four	Rapid Fire	1	300	"D"	10	Standing to Prone	3pt / Loop
Stage Five	Slow Fire	10	500	"B-MOD"	10	Prone	3pt / Loop
				Total	50		

During this table, the following ITS are introduced at the Entry Level Sites.

a. 0300.M16.1005 Engage targets from a prone position with a service rifle/carbine.

b. 0300.M16.1006 Engage targets from a sitting position with a service rifle/carbine.

c. 0300.M16.1007 Engage targets from a kneeling position with a service rifle/carbine.

d. 0300.M16.1008 Engage targets from a standing position with a service rifle/carbine.

e. 0300.M16.1009 Engage targets at the sustained rate of fire with a service rifle/carbine

f. 0300.M16.1010 Perform the Fundamentals of Marksmanship (Table 1) with a service rifle/carbine.

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APPENDIX B. COURSE OF FIRE FOR TABLE 2 (BASIC COMBAT RIFLE MARKSMANSHIP)

a. Table 2 Training (Day 1)

	Distance (yards)	Drill	Position	Iterations	Rounds Per Drill	Time (sec)
BZO	300	BZO	Prone	1	10	NA
Stage One Position Refinement	25/50	Live-Fire Prep	Standing	NA	24	NA
Stage Two Presentation	25/50	Head Shot	Standing	2	1	3
	25/50	Controlled Pair	Standing	2	2	4
	25/50	Failure to Stop	Standing	2	3	5
Stage Three Position Change	25/50	(2)Controlled Pairs	Standing to Kneeling	2	2	5
	25/50	(2)Controlled Pairs	Standing & Kneeling	2	4	7
	25/50	Failure to Stop	Standing to Kneeling	2	3	8
Stage Four Multiple Targets w. Position Change	25/50	(2)Controlled Pairs	Standing	1	4	6
	25/50	(2)Controlled Pairs	Standing & Kneeling	2	4	9
	25/50	(2)Failures to Stop	Standing to Kneeling	2	6	10
Stage Five Speed Reloads	25/50	(2)Controlled Pairs	Standing & Kneeling	5	4	10
Stage Six Moving Targets	100/200	Movers Right	Standing to Kneeling	3	2	10
	100/200	Movers Left	Standing to Kneeling	3	2	10
				Total Rnds	120	

b. Table 2 Pre-Evaluation and Evaluation (Day 2)

	Distance (yards)	Drill	Position	Iterations	Rounds Per Drill	Time (sec)
Stage One Presentation	25/50	Head Shot	Standing	2	1	3
	25/50	Controlled Pair	Standing	1	2	4
	25/50	Failure to Stop	Standing	1	3	5
Stage Two Position Change	25/50	Controlled Pairs	Standing & Kneeling	1	4	7
	25/50	Failure to Stop	Standing to Kneeling	1	3	8
Stage Three Multiple Targets w. Position Change	25/50	(2)Controlled Pairs	Standing	1	4	6
	25/50	(2)Controlled Pairs	Standing & Kneeling	2	4	9
	25/50	(2)Failure to Stop	Standing to Kneeling	2	6	10
Stage Four Speed Reloads	25/50	(2)Controlled Pairs	Standing & Kneeling	1	4	10
Stage Five Moving Targets	100/200	Movers Right	Standing to Kneeling	2	2	10
	100/200	Movers Left	Standing to Kneeling	2	2	10
				Total Rnds	50	

The following ITS are introduced at the Entry Level Sites.

a. 0300.M16.1011 Demonstrate weapons carries with the service rifle/carbine.

b. 0300.M16.1012 Execute a Tactical Reload with a service rifle/carbine.

c. 0300.M16.1013 Execute a Speed Reload with a service rifle/carbine.

d. 0300.M16.1014 Execute Controlled Pairs with a service rifle/carbine.

e. 0300.M16.1015 Execute Failure to Stop Drills with a service rifle/carbine.

f. 0300.M16.1016 Execute Multiple Target Engagements with a service rifle/carbine.

g. 0300.M16.1017 Engage a Moving Target with a service rifle/carbine.

h. 0300.M16.1018 Perform Basic Combat Marksmanship Skills (Table 2) with a service rifle/carbine.

APPENDIX C. DEPLOYABLE MILITARY TRAINER SIMULATION SYSTEM

Meggitt Training Systems' Deployable Military Trainer supports both individual and collective/unit training across the full spectrum of military operations. A single-screen system provides a 10-foot wide visual field. Each system includes 8 weapon ports for use with either tethered or Blue Fire® wireless weapons. Designed for space-conscious organizations, the system can be placed at various focal lengths to accommodate multiple firing line distances.

The system is designed to be operational within 15 minutes for the novice operator.
The Deployable Military Trainer is delivered with appropriate courseware to support training in marksmanship, judgmental and collective/unit training. Marksmanship training encompasses short- and long-range pop-up or stationary targets. Judgmental training provides shoot/don't shoot video scenarios, target discrimination and multiple scenario selection. Unit training builds on the individual skills training capability of the system by allowing interaction, command and control and impact of the decisions of other members of the unit. The system includes robust editing tools in judgmental and collective training for use by the instructor wanting to build unique, unit-specific training scenarios. The system can be networked globally and is HLA DoD compliant.

Supporting a full range of military weapons, the Deployable Military Trainer provides an accurate simulation of weapon ballistics including the effects of wind speed and direction. Weapon aim point, shot location and the number of rounds fired are a few of

the measurements that are identified in the shot feedback screen display. Barrel positions, weapon aim point trace, trigger pull and butt pressure are measured and monitored in real-time for the training instructor.

APPENDIX D. WIRELESS (TETHER-LESS), SIMULATED WEAPONS TECHNOLOGY (M16A2)

Meggitt Training Systems Blue Fire Wireless Weapon Simulators use commercial wireless Bluetooth technology to communicate with the training system in the same manner as our System Controlled Weapons. For weapons with recoil, this is achieved with a rechargeable magazine of compressed gas. This is significant in that while not tethered, Blue Fire weapons still retain the full sensor feedback. These patented Blue Fire weapon simulators can be used in conjunction with other System Controlled Weapon simulators without modification.

Magazines can be refilled in just a few seconds with either compressed air or nitrogen. Our filling station is designed to accept any of our Blue fire® magazines and refill each one with a quick depression of the handle. Nitrogen gas for refilling can be obtained from your local gas supplier or you can use a SCUBA tank that can be refilled at any SCUBA shop.

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APPENDIX E. TETHERED WEAPONS (M4)

Meggitts Systems-Controlled Weapon Simulators are high in fidelity and built to tolerances within 10% of the live weapons weight and center of gravity. Systems-Controlled Weapons are tethered to the training system to provide the highest degree of weapon control and feedback. For example, Systems-Controlled Weapons support real-time transmittal and display of weapon handling data to the instructor in the form of displayed weapon sensor data. The instructor can initiate weapon jams via instructor keystroke, designated elapsed scenario time, and/or designated number of shots fired. Compressed air or CO2 gas provides recoil that is sufficient to disturb the trainee sight picture, requiring the trainee to reacquire the target after each shot.

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APPENDIX F. MEGGITT TRAINING SYSTEMS, INC

ADDITIONS/OPTIONS/EXPANSION

HLA Networking
Indirect Fire and Close Air Support package
External Pilot Station for Pilot-in-the-loop CAS training
Head Mounted Display for quick 360 degree location of targets
Additional screen kit (includes a projector, hit-detection camera unit, image-generator, and associated cabling)

SHOT FEEDBACK (MAIN SCREEN)

Shot hit point (multiple targets – up to three simultaneous targets)
Number of rounds fired
Symbol denoting direction of missed shot
Score by region
Identifies frame of target at shot impact time on animated targets
Interactive targets (based on authored course)
Weapon shot sounds (unique)
Bullet hole on target
Explosions (Hit/Miss)
Airburst explosions
Tracers
Shot splash
Depict anti-tank and grenade rounds flying downrange (if visible during live fire)
Wind flag (denotes direction and speed; wind flag position is configurable)
Raising and lowering of targets with spotting
Occulted targets
Animated targets

ACCURACY

Accurate firing simulation of weapon
Accuracy – 0.20 mrad
Fixed sight ballistics
Adjustable sight ballistics
Effects of wind speed and direction on ballistics
Dual sight ballistics
Effects of weapon cant
Weapon Procedures
“Load/Unload”
“Make Safe”
“Jam/Clear”
“Immediate Action Drills”

Multiple procedures for one weapon

SCENARIO CONTENT

Printed terrain maps
Setup improvised explosive devices (IEDs) Ability to lay anti-personnel and anti-vehicular minefield

FIRE MISSIONS

Artillery/Mortar missions to include HE, Smoke, Illumination, DPICM, WP, RAAMS,ADAMS, CPHD
Field guns (105mm, 155mm, etc.)
Naval guns (4.5-in, 5-in, 76mm)
Mortars (60mm, 81mm, 120mm)
SFMG
CASEVAC missions
Fixed/Rotary Wing CAS mission
AC-130 Gunship missions
Bomber CAS missions
Mark friendly locations (VS-17 panels, smoke, IR strobes)

SUPPORTED WEAPONS

Rifles/Carbines
Machine Guns (sub, light, heavy, general purpose)
Shotguns
Pistols
Anti-tank weapons
Rifles with grenade launchers
Automatic grenade launchers
Mortars

SUPPORTED DEVICES

HMMWV Motion Platform base simulator
Binoculars
Simulated laser range finder
Virtual LRF/LTM
Head mounted displays

INSTRUCTOR MONITORING (REAL-TIME)

Weapon aim point trace
Weapon sensor feedback (can include cant angle, trigger squeeze, butt pressure, rounds left, safety, round in chamber, elevation, many others)
Course results

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California